FOREST COMMUNITIES OF SOUTH BASS ISLAND, OHIO[1]

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ABSTRACT

Distribution of the tree species in present-day woodlots on South Bass Island appears to be related mainly to the stage in succession, which apparently correlates directly with the length of time available for reforestation since the initial extensive cutting. Such reforestation has occurred primarily in places where bedrock is so shallow that the land has been rejected for vineyard use or for human development. Substrate apparently does not control the distribution of the tree species, as bedrock throughout the forested areas of the Island, with one exception, is uniformly Silurian Put-in-Bay Dolomite, which is very shallow and locally exposed, and in which Romeo (Randolph) soils have been developed. The exception is the Box Elder-Green Ash woods, located on the northeast end of the Island, where bedrock is unusually deep (17½ feet) and is covered by till, in which Hoytville (Catawba loam) soils have been formed.

Six arborescent community types are recognized in the Island's remaining woodlots, the distributions of which have been mapped. Earliest in successional development of the communities is Young Hackberry, represented by Miller's Woods, followed by Hackberry-Blue Ash, represented by woodlots north of the lighthouse. Also early in succesion are the Box Elder-Green Ash community, as found on the northeast end of the Island, and the Cedar woods, represented by Heineman's Woods, which owes its great abundance of cedar to intensive grazing during the mid-1940's. A more mature type is the Sugar Maple-Hackberry-Basswood community, represented by Victory Woods and Cooper's Woods, and most mature of all is the Maple-Oak-Hickory type, as found in Duff's Woods.

The more mature woodlots on the Island, where the dark, organic-rich Romeo soils are relatively thick, are characterized by a predominance of *Acer saccharum* in all size classes. Next in importance is *Celtic occidentalis*, which is present in most woods, but which predominates only in submature woods with abundant dolomite bedrock outcrops, where the Romeo soils are thinner. *Tilia americana* is usually third in importance, although its values are normally much lower than are those of the two dominant species, and it is generally represented by only a few large trees and no saplings. Other species, such as *Prunus serotina, Morus alba, Juniperus virginiana, Fraxinus quadrangulata, Ostrya virginiana, Ulmus rubra,* and *Quercus muehlenbergii,* have far lower importance values. Of these, the first four are regarded as successional, the first-named species being the earliest in the successional sequence, and the last four are considered to be minor members of the mature community.

The scattered individuals of oaks (*Quercus alba* and *Q. rubra*) and hickories (*Carya* sp.) which occur in the Maple-Oak-Hickory community are the most difficult to explain, because of their limited distribution and because of the lack of any apparent correlation between their occurrence and either the substrate or the successional sequence which appears to control the distribution of the rest of the tree species. These oaks and hickories are believed to represent the normal climax associates of such stands, interpreted to occur in such restricted numbers only because of the extreme favorableness of the dark, organic-rich soil on the shallow dolomite bedrock for *Acer saccharum.*

INTRODUCTION

The arborescent vegetation of South Bass Island is composed of relatively few species, all of which also occur commonly in other parts of Ohio. Nonetheless, the vegetation here, and also on adjacent islands of the Erie Archipelago and parts of Catawba peninsula to the south, appears to be unique.

The vegetation of the island was called "maple-basswood" by Braun (1950), though her reference to the area was extremely general. *Acer saccharum* is indeed present in unusual abundance, but *Tilia americana*, though a consistent member of the canopy, is not common. Gordon, on his map of the original natural vegetation of Ohio (1966), shows the vegetation as "oak-sugar maple," and then, in his book (1969), expands the title to the "Oak-Maple-Basswood Association." According to Gordon, this Association is correlated with the occurrence of the Catawba (Hoytville) soils and has a canopy dominated by *Quercus alba*, *Q. rubra*,

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Acer saccharum, *A. nigrum*, *Juglans nigra*, *Fraxinus americana*, *Ulmus rubra*, *Tilia americana*, *Prunus serotina*, *Carya cordiformis*, and *C. ovata*. In addition, *Aesculus glabra*, *Ostrya virginiana*, *Celtis occidentalis*, *Gleditsia triacanthos*, and *Fraxinus quadrangulata* are cited as indicator (successional) species in sparcely wooded area formerly occupied by this association.

The arboreal vegetation of the island has been described in a little more detail by Hudgins (1953), Core (1948), and Langlois and Langlois (1948), though their publications simply cite the tree species present in two main communities, associated with the two main island soils. These communities were believed to represent the original island vegetation prior to settlement. In the community occurring on the deeper Catawba (Hoytville) soils (the Oak-Maple-Basswood Association), *Acer saccharum* and *Celtis occidentalis* are described as being very abundant on the more mesic sites, with fewer numbers of *Juglans nigra* and *Ulmus rubra*. *Quercus alba* is reported to be important on the slightly drier sites, with *Quercus rubra*, *Q. muehlenbergii*, *Carya glabra*, and *C. ovata* as associates. The community occurring on the shallower Randolph (Romeo) soils, the Hackberry-Blue Ash Association, is reported to be composed of very abundant *Celtis occidentalis*, with less abundant *Fraxinus quadrangulata*, and with *Ulmus rubra*, *Acer saccharum*, *Quercus muehlenbergii*, and *Ostrya virginiana* as subdominants. This association is described as an edaphic type, favored by the thin limestone soil, which would be succeeded by the Oak-Maple-Basswood Association as a deeper, more mature soil developed. Red cedar, cited as abundant in early descriptions of South Bass and Kelley's Islands, was probably largely restricted to ledges and cliffs bordering the lake (Core, 1948). In none of these earlier reports are quantitative data on the vegetation presented.

McCormick (1968), in a study of the vegetation in fallow vineyards of South Bass Island, noted the occurrence of certain overstory species in these areas. He inferred that secondary succession would lead to a forest composed predominantly of *Acer saccharum*, with *Celtis oc identalis*, *Quercus rubra*, and *Juglans nigra* as associated canopy species, though this interpretation represented considerable extrapolation beyond the fallow-vineyard vegetational data.

Even a cursory examination of the wooded areas remaining on South Bass Island would suggest that the arborescent vegetation is quite different from the "original vegetation" reported by many of the authors referred to above. *Acer saccharum* is the most abundant species everywhere, followed by *Celtis occidentalis*, especially in areas characterized by earlier successional stages, while *Tilia americana* is uncommon, and the several species of *Quercus* and *Carya* occur only as scattered individuals in a few areas. In order to establish the true nature of the forest vegetation remaining on South Bass Island, and to determine the observable effects, if any, of the substrate on the composition of the tree communities, a joint investigation was initiated.

The purposes of this study were (1) to map in detail, using large-scaled aerial photographs, the distribution of the most important individual tree species (except for *Acer saccharum*, whose overwhelming abundance made mapping of it impractical) composing the canopy in the remaining wooded areas of South Bass Island; so as (2) to determine, from this mapping, the major late successional arborescent communities present on the island; and (3) to attempt both to explain the relationship of these communities to each other, in terms of a successional pattern, and to infer the nature of the probable climax vegetation of the island. To aid in this evaluation, the tree vegetation of the five major forest communities recognized was sampled quantitatively. These data were then compared with an island-wide survey of the geological substrates, and with as much information on the early land-use history of the island as could be located, in an attempt to explain the distribution of the major tree species and the differences between the arborescent communities they compose. In addition, qualitative data on the same tree species on most of the other islands in the Erie Archipelago were collected for comparison with the South Bass Island data. Early successional communities, such as those in oldfields, or on gravel or rocky shorelines, were not considered.

Because of their size, copies of the large-scaled aerial photographs, on which the original detailed mapping of individual trees was done, are not included. However, these photographs are on file at the Biology Department of Bowling Green State University, where they may be seen upon request.

LOCATION AND DESCRIPTION

South Bass Island is the largest of the Bass Islands, and the third largest of the 20 islands comprising the Erie Archipelago in the shallow western basin of Lake Erie. It is located about three miles north of Catawba Point and 35 miles east of Toledo, Ohio, at longitude 82° 50′W and latitude 41° 39′N, in Ottawa County. The island, which is elongated in a northeast-southwest direction, is about three and three-fourths miles long and one and one-half miles wide at its widest point, with a surface area of approximately 2.36 square miles (McCormick, 1968).

The shoreline is rocky, for the most part, with high abrupt wave-lashed cliffs on the northwestern side and flat, gently sloping rocky shores on the southeast. The land surface is without streams, and varies in elevation from that of the lake (570 feet) to more than 640 feet above sea level at Victory Hill, the highest point on South Bass Island.

The climate of South Bass Island is much less extreme than is that of the Ohio mainland, being ameliorated by the presence of the lake. The island has the longest frost-free season (205 days) and the lowest annual precipitation (28.99 inches) recorded for the state, with a mean annual temperature of 50.2°F (Hudgins, 1943; Verber, 1955). The prevailing winds are predominantly from the southwest during the growing season and from the northeast during the winter. Storm winds in both seasons come mostly from the north and northeast. Strong winds, severe storms, fog, freezing rain, and spray and hail are common, especially in the winter (Langlois and Langlois, 1948). McCormick (1968) describes the island vegetation as unusually luxuriant, which he explains as being due either to upward water movement from the lake and water table or to a low precipitation-evaporation ratio.

SUBSTRATE CHARACTERISTICS

Geologically, the Lake Erie Islands represent the emergent sections of the summits of two north-south ridges, or cuestas, formed by the erosion of a series of gently eastward-dipping sedimentary rocks of differing resistance (Carman, 1946). The resistant rock layer which forms the eastern cuesta, on which are located Kelley's, Middle, and Pelee Islands (and also Marblehead Peninsula) is the Columbus Limestone of Devonian age. The western cuesta is composed mainly of Put-in-Bay Dolomite (together with the overlying Raisin River Dolomite and the underlying Tymochtee Shaly Dolomite, all of Silurian age) and makes up the remainder of the islands in the Erie Archipelago: the three Bass Islands; West, Middle, and East Sister Islands; North Harbor; and the Hen and Chickens Group (and also Catawba peninsula) (Carman, 1927 and 1946; Core, 1948; Forsyth, 1971; Forsyth *in* Stuckey and Duncan, In prep.).

Most of the rock cropping out on South Bass Island is Put-in-Bay Dolomite (Mohr, 1931; Sparling, 1968 and 1970; Forsyth, 1971), a hard, light-grey dolomite (magnesium-bearing limestone) with massive bedding. The underlying Tymochtee Shaly Dolomite is visible only locally, near the base of the western cliffs at the State Park and near the lighthouse, where, because of its shaly nature, it is easily recognized (Mohr, 1931; Sparling 1965, 1970, and 1971).

Because the Tymochtee Dolomite is not present at the surface of South Bass

Island, it does not contribute to the Island's substrates and therefore plays no direct role in the distribution of forest species or forest communities here. However, it is believed to have contributed to the producing of some of the irregularities of the land surface because of solution dissolving some of the soluble gypsum occurring in it, thus causing collapse of the overlying rocks and producing large circular depressions in the landscape, with caves common around their margins (Verber and Stansbery, 1953). The rock unit overlying the Put-in-Bay, the Raisin River Dolomite (which is also a grey dolomite, being only somewhat less resistant than and differing only slightly in appearance from the Put-in-Bay Dolomite), occurs at the surface of South Bass Island along the eastern shore

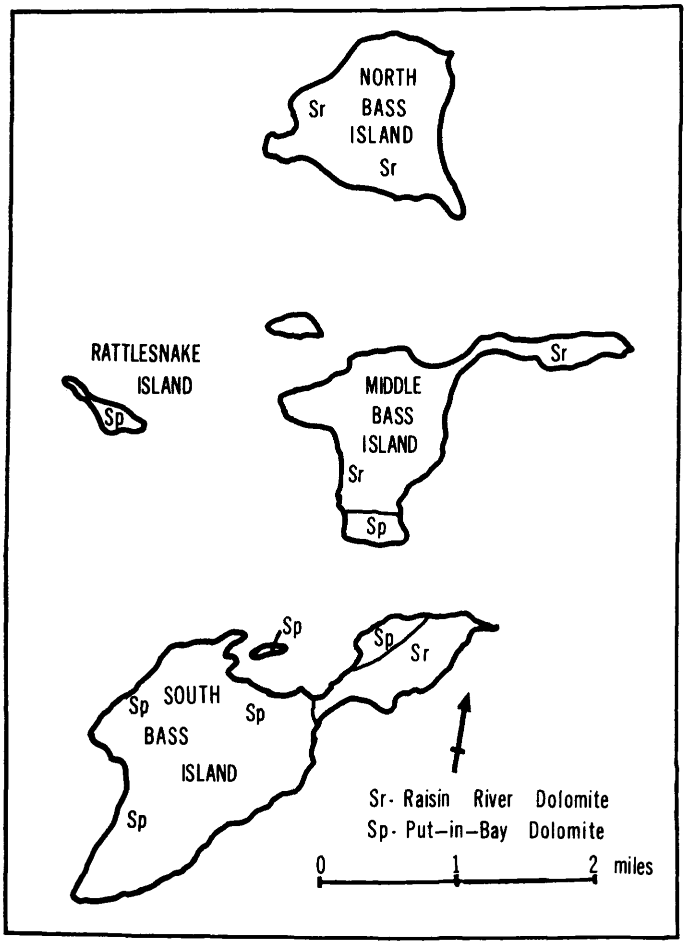

FIGURE 1. Bedrock geology of the Bass Islands.
(drawn from Mohr, 1931 and Sparling 1965, 1970, and 1971)

and in the Buckeye Point area (fig. 1) (Mohr, 1931; Sparling, 1965, 1970, and 1971). Mature forests are lacking in these areas, so clearly this rock also plays no role in this study.

All the forested areas whose vegetation was sampled in this study occur in areas underlain by the Put-in-Bay Dolomite. If the substrate plays any part in explaining the distribution of the different tree species and woodland communities present, therefore, it must be factors unrelated to rock type, such as the depth of the dolomite bedrock and/or the nature of the surficial deposits present on top of the rock, that are critical.

Bedrock is shallow over almost all of the island (figs. 2 and 3). In many places, the rock is exposed, especially along the high, northwestern shore, where it forms steep, craggy cliffs. In the woods adjacent to these cliffs and also in other areas of extremely shallow bedrock farther from this shore, the rock characteristically displays a rough, irregular surface, appearing like a mass of miniature pinnacles separated by small, steep-sided, funnel-shaped depressions filled with dark, organic-rich soil. Although these depressions are enclosed, in no place do they hold water, and the appearance of the entire exposed surface, both pinnacles and depressions, suggests a very dry, well-drained condition.

An observable drop-off of the land surface, with the lower land to the southeast, occurs about half a mile back from the rocky northwest shore. This drop-off is low (a drop of 10 to 30 feet), but is fairly abrupt in most places, with abundant outcropping rock where it is highest. It can be traced, as a fairly persistent northeast-southwest feature, across the entire length of South Bass Island, from the north side of Terwilliger's Pond, just south of the Dickerman and Moizuk residences, where this drop-off is clearly visible, to near the Verduin residence on Mitchell Avenue, to the hill above the sanitary landfill, to Castle Inn on Niagara Road, and the attendant's house at the State Park. It even shows in the ancient pictures of the Victory Hotel that once stood on the site of the present State Park (Frohman, 1971). All the sites from which excessive depths to bedrock have been reported on South Bass Island occur just southeast of this feature: 31 feet near the Miller ferry dock (value obtained from Ohio Division of Water well data), 64 feet at the upper (west) end of Terwilliger's Pond (Ernest H. Miller, personal communication, 1968), 35 feet at George Heineman's residence on Mitchell Avenue (from Ohio Division of Water well data), and reportedly a depth of several tens of feet near Castle Inn. Many residents of the island believe that there is a deep, continuous buried valley present along the base of this linear ridge, along the belt from in which these unusually deep rock depths have been reported.

In order to check on the presence of such a valley in the area west of Mitchell Avenue, and also to test for bedrock depths in some other critical locations on the island, depth-of-rock determinations were made at eleven different sites, using the Geology Department's portable seismograph. Six readings were made along a line parallel to Mitchell Avenue, west of the Verduin residence (fig. 2). Station 1 was located on a bedrock outcrop to the northwest, just north of an old gravel excavation, and subsequent stations were located along a line extending southeast across the old gravel pit to a point well beyond the edge of the presumed buried valley. No value greater than six feet was obtained (fig. 2 and values shown in squares in fig. 3). A greater depth—27 feet—was recorded along the edge of Mitchell Avenue just northeast of this series of stations and fifty feet south of (and a few feet lower than) the George Heineman residence (where a water well had revealed bedrock at a depth of 35 feet some years ago). Clearly no true "buried valley" exists here, and if all the deep records are to be believed, only a discontinuous series of deep depressions are present, some of which may well be especially deep sinkholes, formed in the dolomite by solution. It is also possible that the deep isolated value near Castle Inn may be a local sinkhole, and that, beginning about at Mitchell Avenue, there may indeed be a buried, filled valley, which opens out and deepens to the northeast; bedrock-surface data for this area are not adequate to refute any of these theories. The steep drop-off to the northwest could be the eroded edge of the valley, or the edge of a line of sinkholes, or the position of an ancient wave-cut cliff (particularly since there is no "other side").

Other places where the portable seismograph was used (fig. 2 and values in squares in fig. 3) were: at two sites in Victory Woods near the northwest end of the vegetation-sampling base line, where values of six and ten feet were obtained (bedrock cropped out at the southeast end of this base line); on the ancient gravel beach on the upland near the lighthouse, where a zero reading was interpreted to mean the presence of large dolomite cobbles, like those forming most of the cobble beaches around the island today; and in the box-elder wood on the northeastern section of the island, where the depth to rock was 17½ feet.

Southeast of the line of the few very great depths to rock, cover is much less thick. In most places the rock is only a few feet deep, as revealed by scattered

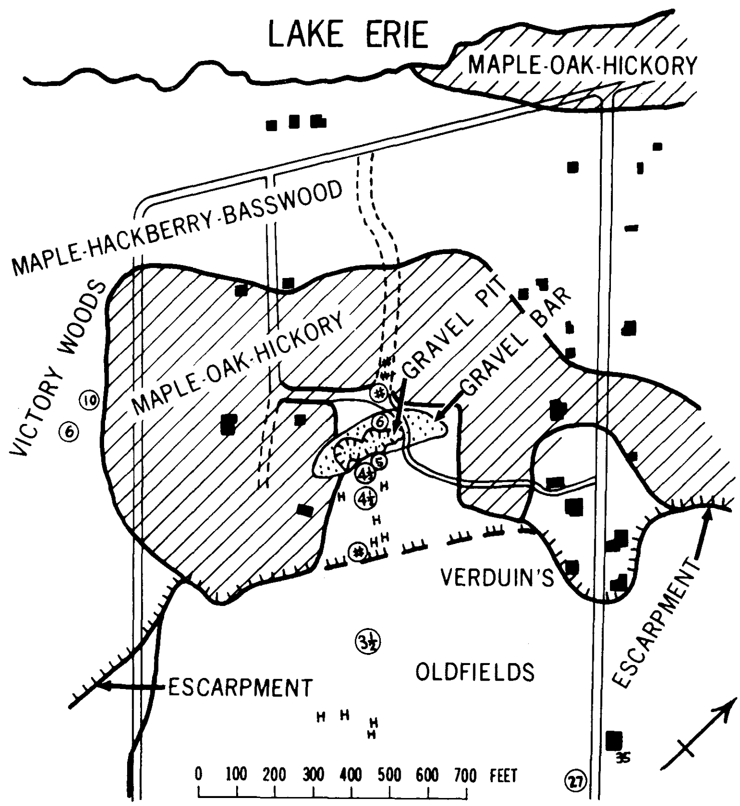

FIGURE 2. Detailed location of determinations of depths to bedrock by portable seismograph in the field behind the Verduin residence and in Victory Woods. Depths to rock (circled) are in feet; # represents bedrock exposed at the surface. H represents occurrence of young *Celtis occidentalis* trees along the line of survey, suggesting the presence of thin soils and shallow bedrock there.

water-well data (provided by the Ohio Division of Water). Elsewhere, as in Heineman's and Cooper's Woods, the rock is locally exposed and is generally quite shallow, being mostly less than a foot deep, as demonstrated by abundant probe tests. Along the southeast shore, bedrock has been exposed by wave erosion in many places, and locally is shallow for distances of a hundred feet or so inland. Greater depths—eight feet or more—are encountered in a few places on the island, such as near the airport and at the northeast end (where the 17½-foot depth was recorded).

The surficial materials, where the bedrock surface is at a depth of no more than a few inches, are a loose accumulation of fragmented and partially decayed organic materials, which produce a dark soil called Romeo (previously called Randolph) (all modern soil terminology given here has been provided by Mr. Donald Urban and Mr. Charles Innis, soil scientists with the Soil Conservation Service, and all earlier terminology is from Paschall, *et al.*, 1928, and as quoted from him by Core, 1948) (Table 1). Romeo soils are well drained and rich in organic nutrients, and also provide good moisture retention (Lutz and Chandler, 1946, p. 297), without being saturated. Where the bedrock surface is much deeper, the material at the surface, covering the rock, is generally clay-rich glacial till, in which a soil best called the Hoytville (previously called the Catawba loam) is developed. Because of its high clay content and because the ground, where this soil is present, is generally very flat, such areas tend to be poorly drained, with standing water persisting on them sometimes as late as early June. Some scattered thin, elongate deposits of gravel, which represent ancient beach deposits now above lake level, are also present, characterized by the Belmore soil (once called the Rodman soil). Such abandoned gravel beaches occur adjacent to and within the cemetery grounds near the lighthouse, just southwest of the Verduin residence on Mitchell Avenue (where the deposit has been mostly excavated), and on the northeast peninsula of the island, where the deposit, which occurs almost parallel to and just east of

TABLE 1
Soils of South Bass Island
(Courtesy of soil scientists with the Soil Conservation Service)

Old Terminology (Paschall, *et al.*, 1938) Name	Mapping symbol	New Classification Name	Mapping symbol	Geologic Condition
Randolph stony loam	Rs	Romeo stony loam	644s	Shallow dolomite bedrock
Rodman gravel	Rg	Belmore loam	9055	Emerged gravel bars
Catawba loam	Cm	*Hoytville clay loam	628	Glacial till (ground moraine)
Catawba gravelly loam	Cg	Rawson loam	2A35	Low sandy gravel bars
Catawba fine sandy loam	Cf	*Seward fine sandy loam	9534	Thin lacustrine sand (over till)
Catawba silt loam	Cl	*Haskins loam	2A25	Lacustrine silt (over till)

*The morphology of these soils, as they appear on South Bass Island, does not exactly fit the official USDA descriptions given for them.

the main road (Columbus Avenue), is especially shallow (fig. 3). Each of these ancient beach deposits is at a different elevation, so each must represent a different prehistoric level of the lake. Thin accumulations of wave-washed silt or fine sand are locally present on top of the till, forming the Haskins soil (formerly called Catawba fine sandy loam), though such materials appear to be less extensive than originally reported, based on modern investigations (Donald Urban, personal communication, 1969). These two sets of soils names and the geologic conditions represented by them, are all summarized in Table 1.

A geologic map of the usual type (fig. 1) would be meaningless as far as any efforts to evaluate vegetational substrates on South Bass Island are concerned, so a map based on depths of bedrock and nature of surficial materials, in places where they are thick enough to be significant, was prepared (fig. 3). This mapping was based mainly on detailed field investigations and available depth-to-rock data, but was aided by a preliminary systematic stereoscopic study of the aerial photographs and the soils map (Paschall, *et al.*, 1938). Four different mapping units are used. (1) Most obvious are the areas where depths to rock are extremely shallow, the dolomite being exposed or averaging only a few inches deep (deeper in local, filled sinkholes), and where Romeo soils occur, such as in the rugged northwestern belt. (2) Areas of slightly deeper bedrock (depths of a foot or so), but still with numerous outcroppings, are present in the middle of the island and also along the southwest shore, occurring in association with the flatter land. These areas are also characterized by Romeo soils. (3)Narrow belts of beach gravel occur above present lake level, and are shown by solid black bands, where Belmore soil is present. (4) Flattest and most poorly drained are the areas where bedrock is eight feet deep or more, and is covered by glacial till (which is capped locally by a thin cover of lacustrine (lake) silt or fine sand), such as in the Box-elder woods studied by McCormick (1968), where Hoytville soils are present. The larger, deeper collapse depressions, believed to have been formed by the solution of gypsum in the underlying Tymochtee Shaly Dolomite (Verber and Stansbery, 1953), are also shown in this figure.

EARLY LAND-USE HISTORY

The present distribution of arborescent species on South Bass Island has been markedly influenced by agricultural practices and by use of the Island's other resources since the time of its settlement in approximately 1810. The original forests were cleared rapidly after settlement to provide cordwood for steam vessels, lumber for the mainland shipbuilding industry, and red cedar for export to Europe. Thus by 1852 most of the marketable timber had been harvested and the cleared land converted to pasture. (All the material in this section has been drawn from the following sources: Hudgins, 1943; Langlois and Langlois, 1948; and McCormick, 1968).

The Island's climate, moderated by Lake Erie, is particularly well suited for viniculture. The early German settlers established the first vineyards in 1854, and by 1890 approximately 600 acres (40% of the island) of the deeper (Catawba) soils were under cultivation. The remaining second-growth wooded areas were thus restricted to the shallower Romeo (Randolph) soils, and were grazed and cut repeatedly for fuel.

The Prohibition Enforcement Act of 1919 was disastrous to the island economy. Although its repeal in 1933 somewhat revived the industry, viniculture has steadily declined, so that by 1942 only 270 acres were under cultivation and one third of The Island was occupied by fallow vineyards that were grazed and mowed for differing periods of time. The numbers of livestock also declined during this period, so that the grazing pressure in the wooded areas decreased.

Individual species of trees were harvested somewhat selectively. Sugar maple was preserved because it served as a source of sugar and syrup. Young cedar was (and is) the only wood used as vineyard fence posts. Hickory, elm, ash, sycamore, and probably oak were cut extensively for lumber and firewood, although some individuals were preserved (and were even transplanted) for use as residential shade trees. Young invading hackberry and sumac were repeatedly cut from abandoned vineyards. Deciduous trees were prevented from reinvading many fields by intensive grazing, allowing the non-palatable cedar to become established. In addition, many oldfields were mowed yearly to enhance the habitat for the pheasants that were sought by members of the hunting clubs.

METHODS

Data on the South Bass Island tree communities were obtained by two methods, mapping of individual canopy trees on large-scaled aerial photographs, and quantitative sampling in quadrats. The major arborescent communities were established by studying the distributions of the individually mapped trees on the aerial photographs, and the quadrant sampling was then used to provide comparable quantitative data for each tree community recognized.

The detailed mapping of the distribution of the major canopy trees was done mostly during the summer of 1967, with additional checking during the summers of 1968 and 1969. Mapping was done on a complete set of very large-scaled (1:500) stereoscopic aerial photographs, taking during January, 1967. When further enlarged (1:100), these photographs permitted identification of individual trees without the aid of magnification. These enlargements were used in the field to map the exact locations, in the remaining wooded areas, of all observed individuals of *Quercus rubra*, *Q. alba*, *Q. muhlenbergii*, *Fraxinus quadrangulata*, *F. pennsylvanica*, *Tilia americana*, *Acer negundo*, *Juniperus virginiana*, and *Carya* sp (*Acer saccharum*, because of its overwhelming abundance, was not so mapped.) These data were then transferred to an aerial photograph of the entire island, which mapping was then used to determine the major arborescent community types and their boundaries.

Quantitative sampling of the tree vegetation was done in five different areas on South Bass Island, each area being an example of a different arborescent community. The most extensive sampling was done in an area of the most common forest community (Sugar Maple-Hackberry-Basswood), Victory Woods, during August, 1968. Soils present in this area are the Romeo soils. Two parallel lines, 190 meters in length and 30 meters apart, were established in a southeast-northwest direction, parallel to the long axis of the woods. The first of these lines, the base line, was initiated approximately 50 meters from the road, on a dolomite outcrop in the woods, at an elevation of approximately 625 feet. This line was extended toward the northwest, through an area where bedrock was very shallow, to a point approximately 620 feet in elevation, where the bedrock was four to six feet deep, about 200 meters from the rocky cliffs of the northwest shoreline. The second line was then laid out parallel to and 40 meters to the southeast of the first line. These two lines were located in what appeared to be the older, more mature portion of the woods, thus avoiding the areas of younger, more disturbed stands farther south and along the northwest shoreline.

Vegetation was sampled by nested quadrats in all stands. Ten ten-by-ten-meter quadrats were spaced ten meters apart and alternated on each side of each sampling line. Within these larger quadrats, individuals more than one inch DBH (diamter at breast height) were recorded by species and DBH. Individuals less than one inch DBH but more than 10 feet tall were tallied simply by species. The sapling layer (composed of individuals more than one foot but less than 10 feet in height) was sampled in four-by-four-meter quadrants located in the southeast corners of the larger quadrats, the number of individual saplings being counted by species. The number of seedlings (those less than one foot tall) was recorded by species in one-half-by-two-meter quadrants, located in the southeast corners of the four-by-four-meter quadrats. Nomenclature for all species is that of Braun (1961).

From these data, the number of trees per size class, the mean number per acre less than and more than one inch DBH, the mean number per acre, the total basal area, and the mean basal area per acre were calculated for each tree species. In addition, both relative and absolute values for density, frequency, and dominance, as well as importance values, were calculated for each species. The total number of individuals, the relative and absolute density and frequency values, and importance values also were calculated for all species surveyed in the sapling and seedling layers.

Calculation of importance values is by a modification of the methods of Curtis and McIntosh (1951) and of Buell *et al.* (1966), and were obtained by totaling the relative values for density, frequency, and dominance, and dividing this total by three. The importance values for all other species considered in the remaining vegetational layers were obtained by dividing the sum of the relative values of density and frequency by two. Thus, these values are comparable in all the vegetational layers sampled, with the maximum importance value in any one layer being equal to 100.

The other four areas from which quantitative quadrat data were obtained were studied early in the summer of 1969. These areas were chosen, from among those relatively mature wooded areas large enough to sample and sufficiently free from disturbance to provide meaningful data, to represent four of the major arborescent communities. These were Heineman's Woods, in the center of the island, just south of the junction of Mitchell and Catawba Roads; Cooper's Woods, contiguous to Heineman's Woods on the northeast; Miller's Woods, at the south end of the island, on the upland directly east of the lime-kiln ferry dock; and Duff's Woods, on the northwest side of the island, half a mile southwest of the town of Put-in-Bay (fig. 4). Soils in all these sites were Romeo, with bedrock shallow and outcrops common. Of the two remaining arborescent community types shown on Figure 4 that were not sampled in this study, one (the Box-elder-Green Ash community, occurring in an area of Hoytville soil) was reported on by McCormick (1968), and the other (Hackberry-Blue Ash community, occurring on Romeo soil) is represented by the woodlot just north of the lighthouse and is the subject of a master's thesis (at Bowling Green State University) and will be reported on at a later date.

Nested quadrats were also used to sample the vegetation in these four areas, and importance values were calculated for each species in the overstory, sapling, and seedling layers, as in Victory Woods. The number of quadrats employed and their placement in each woodlot depended upon the size and shape of the area available for study; 32 quadrats were used in Heineman's Woods, 16 in Cooper's Woods, 14 in Miller's Woods, and 12 in Duff's Woods. Ecotonal areas and disturbed sites, such as those affected by localized cutting or by clearing for roads, were avoided. In addition, in an attempt to interpret the order of succession, observations were made in abandoned vineyards of different ages and in other small wooded areas throughout South Bass Island to supplement the quantitative data from the more extensive stands.

RESULTS

Distributional data for the arborescent species mapped suggest that six basic community types can be recognized on South Bass Island: Sugar Maple-Hackberry-Basswood, represented by Victory Woods and Cooper's Woods; Maple-Oak-Hickory, represented by Duff's Woods; Hackberry-Blue Ash (data to appear in Bowling Green State University master's thesis, not yet completed); Young Hackberry, represented by Miller's Woods; Box Elder-Green Ash (studied by McCormick, 1968, who identified the ash as *Fraxinus americanus*); and Cedar, represented by Heineman's Woods (fig. 4). Major tree species present in and characterizing each of these communities are identified by the community names; more complete characterizations of the arboreal compositions of these communities are given below in the descriptions of the vegetation in the woodlots in which the communities occur.

The trees in Cooper's Woods and particularly in Duff's Woods are large and form a high canopy, so these stands are considered to represent more mature woods. In contrast, the trees in both Heineman's Woods and Miller's Woods are relatively small, suggesting that these are younger stands, representing earlier stages in succession. In terms of actual species, trees found in Cooper's Woods or Duff's Woods, but not in Heineman's or Miller's Woods, are considered to come later in the successional sequence, whereas trees found only in Heineman's and Miller's Woods are interpreted to be earlier. Although these trees are considered to be early in the successional sequence, no attempt was made to include in this study the other, still earlier, successional oldfield and scrub species and communities that are abundant on this island (already described by McCormick, 1968).

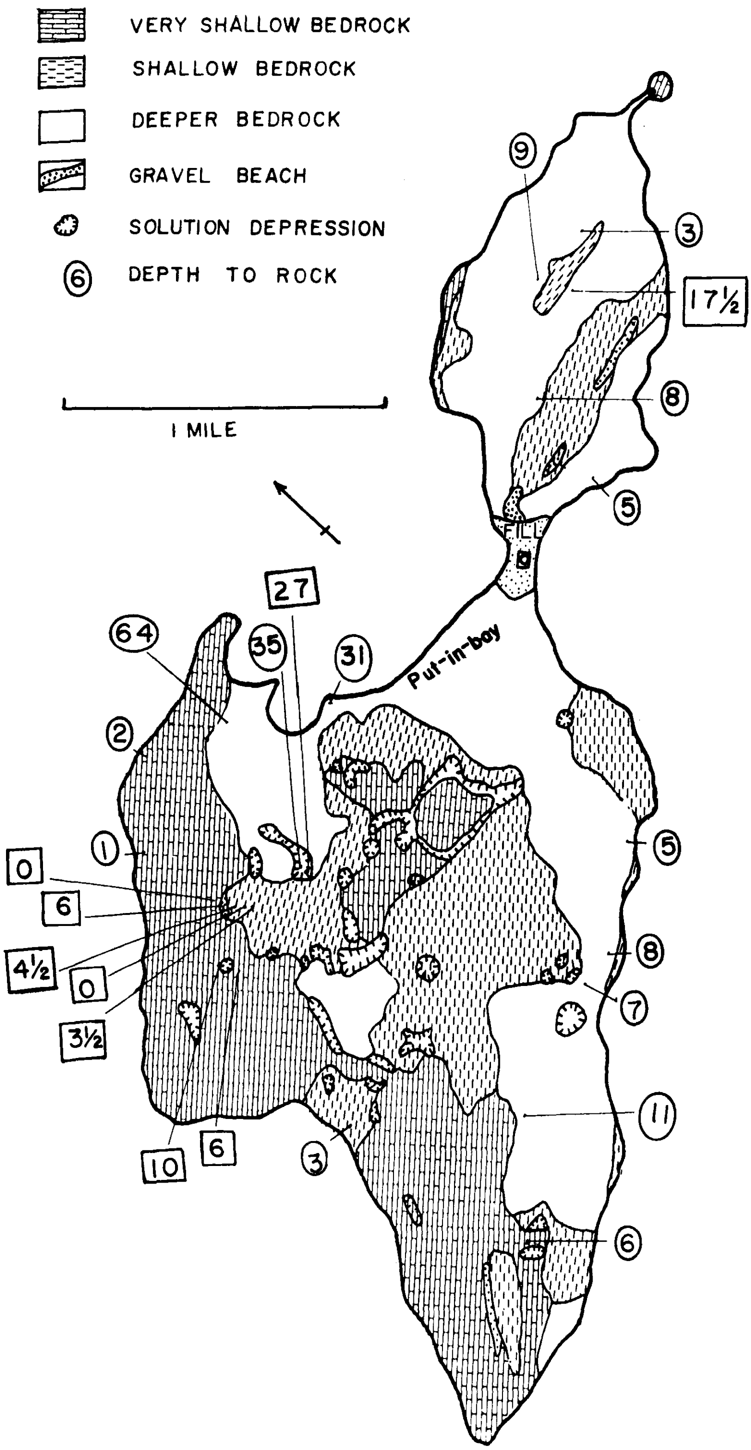

FIGURE 3. Geological substrates of South Bass Island, Ohio. Boxed numbers represent depths to bedrock determined with portable seismograph; circled numbers identify depths to rock derived from well records and reports from island inhabitants.

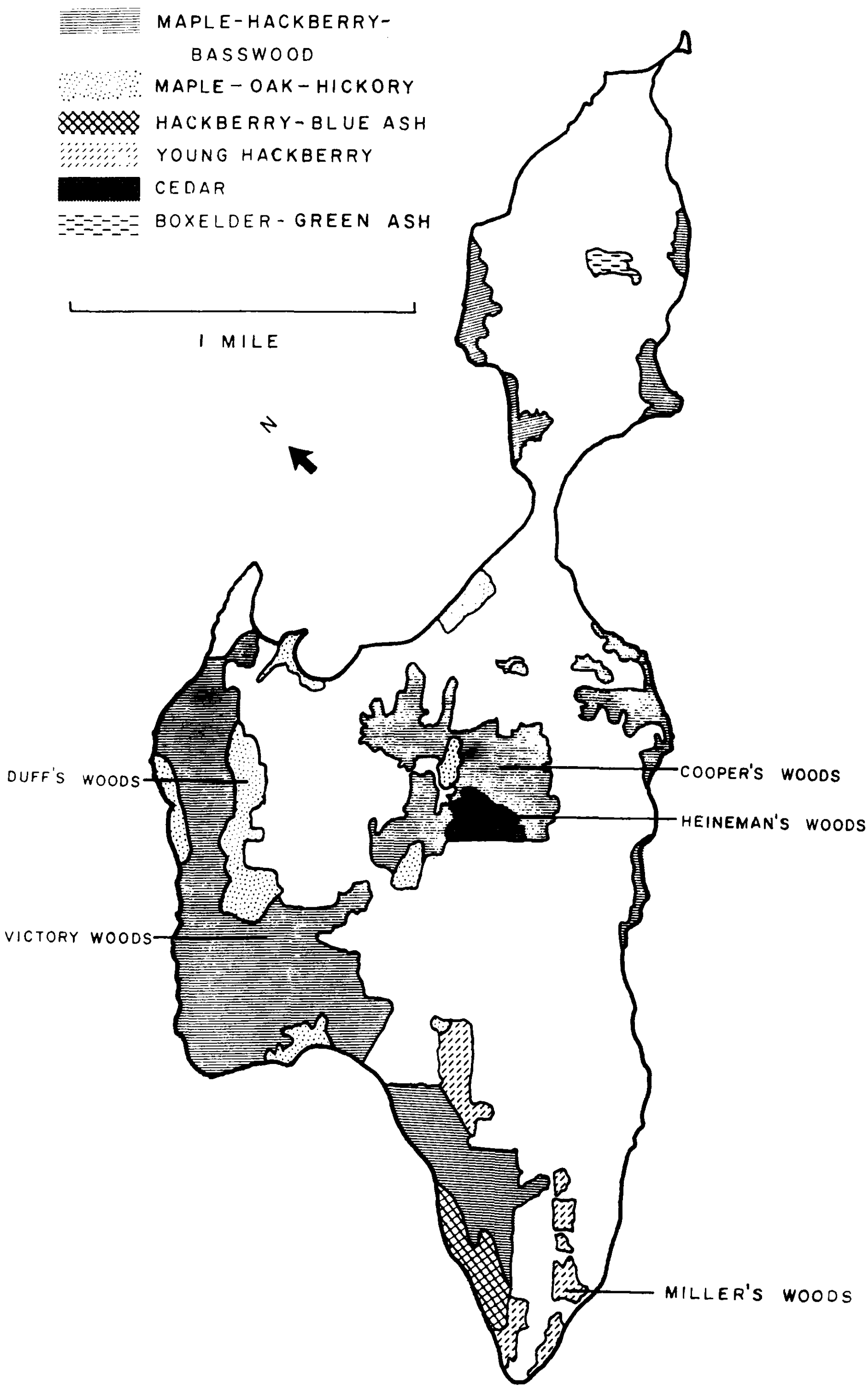

FIGURE 4. Major arborescent communities of South Bass Island showing locations of woodlots sampled in detail.

TABLE 2.
Tree data for Victory Woods, South Bass Island, Ohio

	Number of Stems per Size Class							Total Stems per Acre		
	<1	1–3.9	4–7.9	8–11.9	12–15.9	>16	Total	<1	>1	Total
Acer saccharum	97	27	18	20	27	9	198	135.4	140.6	276.3
Celtis occidentalis	96	30	6	2	1	0	135	134.0	54.4	188.4
Tilia americana	4	5	3	3	3	0	18	5.6	19.5	25.1
Ulmus rubra	1	1	3	0	1	2	8	1.4	9.8	11.2
Quercus muhlenbergii	0	0	0	0	1	0	1	0.0	1.4	1.4
Fraxinus quadrangulata	8	1	0	0	1	0	10	11.2	2.8	14.0
Ostrya virginiana	0	1	0	2	0	0	3	0.0	4.2	4.2
Carya sp.	0	0	0	1	0	0	1	0.0	1.4	1.4
Morus alba	1	1	0	0	0	0	2	1.4	1.4	2.8
Prunus virginiana	1	0	0	0	0	0	1	1.4	0.0	1.4
Totals	208	66	30	28	34	11	377	290.4	235.5	526.2

The Sugar Maple-Hackberry-Basswood community is typically represented by Victory Woods, the most completely studied of all the Island's woodlots. This Woods is dominated by *Acer saccharum* and *Celtis occidentalis*, which together account for slightly more than 88 percent of the total stems and 83 percent of the total basal area (Table 2). *Tilia americana* and *Ulmus rubra* are the next most importance species here, being far more important than the remaining six species listed (Table 2). In the cases of both *Tilia americana* and *Ulmus rubra*, however, the basal-area figures are misleading, as their high values result from the presence of only a few individuals in the larger size classes; in terms of total numbers of individuals, they are relatively unimportant. *Acer saccharum*, on the other hand, is fairly evenly distributed throughout all the size classes (Tables 2 and 3). *Celtis occidentalis*, although it is present in all but the smallest size class, is most important in the smaller stem classes (Table 3).

The importance of *Acer saccharum*, and to a less extent *Celtis occidentalis*, is evident when the values for relative density, frequency, dominance, and importance are compared (Table 2). *Acer saccharum* exhibits by far the highest values in all categories, its importance value being approximately three times as great as that of *Celtis occidentalis*. Even though *Tilia americana* ranks third and *Ulmus rubra* fourth, the total of their importance values taken together does not equal even that of *Celtis occidentalis*. The importance values of the remaining species show their contribution to the vegetation to be relatively minor.

These same trends are evident in the reproduction data (Table 3). Approximately 95 percent of all seedlings and 76 percent of all saplings are *Acer saccharum*, which far surpasses all other species, including *Celtis occidentalis*. This latter species ranks second in these categories, though its importance values are much lower than are those of *Acer saccharum*. Nevertheless, its importance values are greater than the total of those of all the other species.

In Cooper's Woods, the other example of the Sugar Maple-Hackberry-Basswood community, *Acer saccharum* is far less important than it was in Victory Woods (Table 4). *Acer saccharum*, in Cooper's Woods, is only slightly more important than *Celtis occidentalis* in the overstory, though this difference in importance is greater in the reproduction (sapling and seedling) data. *Tilia americana* ranks third and exhibits its highest arborescent importance value in all the

TABLE 2—(*Continued*)

Basal Area								
Total	Per Acre	Density	Frequency	Dominance	Relative Density	Relative Frequency	Relative Dominance	Importance Value
9,642.8	13,456.7	6.8	93	332.5	51.1	43.7	78.7	57.8
557.8	778.4	4.7	41	19.2	35.3	19.2	4.5	19.7
791.6	1,104.7	0.6	38	27.3	4.5	17.8	6.5	9.6
763.9	1,066.0	0.3	14	26.3	2.3	6.6	6.2	5.0
128.7	179.6	0.1	4	4.4	0.8	1.9	1.0	1.2
150.9	210.6	0.4	7	5.2	3.0	3.3	1.2	2.5
152.2	212.4	0.1	4	5.3	0.8	1.9	1.3	1.3
65.1	90.0	0.1	4	2.2	0.8	1.9	0.5	1.1
5.8	8.1	0.1	4	0.2	0.8	1.9	0.1	0.9
0.0	0.0	0.1	4	0.0	0.8	1.9	0.0	0.9
12,258.8	17,106.5							

Island's woodlots in this stand, though its reproduction is extremely small. *Prunus serotina* has extremely small importance in the canopy, but shows a little more in the seedlings and sapling data. *Ulmus rubra* is hardly represented in any of the three layers. Though differences in vegetational composition exist between Cooper's Woods and Victory Woods, both contain the three species, *Acer saccharum*, *Celtis occidentalis*, and *Tilia americana*, as their only important species, the importance values of these three being greatest for *Acer saccharum* and least for *Tilia americana*. Because of this strong similarity, especially when the species composition of these woodlots is compared with that of the other woods studied, the arborescent communities found in both Victory Woods and Cooper's Woods appear to be the same.

The Maple-Oak-Hickory community is found in Duff's Woods, which contains the largest number of large trees and appears to be the least disturbed woodlot of all those on the Island. *Acer saccharum* is the dominant species in all layers in this woods, being far above all the other species in its importance values (Table 4). *Carya* sp. ranks second in importance, though its value is less than half that of *Acer saccharum*, and it is closely followed by *Quercus alba* and *Celtis occidentalis*, in that order. This is the only area, of all those studied, where the importance value for *Acer saccharum* in the canopy is more than four times that of *Celtis occidentalis*. The reproduction data indicate a similar relationship in the sapling layer and the complete absence of *Celtis occidentalis* in the seedling layer. *Quercus rubra* is also present in this stand, although its importance value is low. *Carya* sp., *Quercus alba*, and *Q. rubra* were not encountered in either the sapling or seedling layers. *Tilia americana* is present in small numbers in both the tree and seedling layers, but it is lacking in the sapling layer. *Fraxinus quadrangulata* is present in very small numbers in all three layers.

The Young Hackberry community occurs in Miller's Woods, where *Celtis occidentalis* shows an importance value more than twice that found in any other Island woods (Table 4). *Acer saccharum* and *Prunus serotina* are next in importance, though together they are less than half the value for *Celtis occidentalis*. *Tilia americana* is next in importance, with an importance value that is quite small but is still larger than those of all the remaining four arborescent species taken together. The reproduction data, on the other hand, show *Acer saccharum* as

TABLE 3.
Sapling and seedling data for Victory Woods, South Bass Island, Ohio

	SEEDLINGS						
	Total Stems	Number Per Acre	Density	Frequency	Relative Density	Relative Frequency	Importance Value
Acer saccharum	227	30,622.3	7.8	76.7	94.0	76.8	85.4
Celtis occidentalis	8	1,079.2	0.3	13.3	3.6	13.3	8.5
Tilia americana	1	134.9	0.03	3.3	0.4	3.3	1.9
Prunus serotina	3	404.7	0.1	3.3	1.2	3.3	2.3
Ulmus rubra	1	134.9	0.03	3.3	0.4	3.3	1.9
Fraxinus quadrangulata							
Morus alba							
Totals	240	32,376.0					

more important than *Celtis occidentalis* in both the sampling and seedling layers, suggesting that, in the future, if undisturbed, the present dominance of *Celtis occidentalis* should give way to *Acer saccharum.*

The Cedar community, represented only by the stand in Heineman's Woods, shows *Juniperus virginiana* to be the most importance species in the present overstory layer (Table 4). It is lacking, however, in the sapling and seedling layers of this woods and, with one minor exception, is not found in any of the other woodlots studied. *Celtis occidentalis* is next in importance in the overstory, followed in order by *Morus alba, Lonicera xylosteum,* and *Acer platinoides.* The sapling layer is dominated by *Lonicera xylosteum,* with *Acer saccharum, Prunus serotina, Acer platinoides,* and *Celtis occidentalis* as minor members, a relationship duplicated in the seedling layer, though the dominance is not quite as strong in this layer.

All of thse woods, as presented in Table 4, are arranged in what is interpreted to be their successional sequence, based on the sizes of the trees present and the occurrence of tree species believed (Braun, 1950; Gordon 1969) to belong in climax forests. On this basis, Duff's Woods is interpreted to represent the most mature forest community now present on South Bass Island, with a community characterized by a dominance of *Acer saccharum,* by *Celtis occidentalis* present in much smaller numbers, and by the presence, in small numbers, of *Quercus alba, Q. rubra,* and *Carya* sp. Victory Woods, with a strong dominance of *Acer saccharum* and smaller numbers of *Celtis occidentalis,* but almost no individuals of the species of *Quercus* or *Carya,* comes next. Also representing the Sugar Maple-Hackberry-Basswood community is Cooper's Woods, though the relative proportions of *Acer saccharum* and *Celtis occidentalis* here are almost even. Both other woodlots, Heineman's and Miller's, have a dominance of *Celtis occidentalis* and little or no *Acer saccharum,* Heineman's Woods having been held in an especially early stage by past disturbance (grazing), thus producing the large stand of *Juniperus virginiana* found there.

DISCUSSION

The five different South Bass Island woodlots that were sampled clearly represent several different stages in succession. In order to determine the probable nature of the vegetational climax of South Bass Island, it was essential to establish the order of these woods (Table 4), and also of each of the tree species mapped

TABLE 3—(*Continued*)

SAPLINGS

Total Stems	Number Per Acre	Density	Frequency	Relative Density	Relative Frequency	Importance Value
292	2,461.9	9.7	80.0	75.2	48.0	61.5
71	598.6	2.4	60.0	18.6	36.0	27.3
4	33.7	0.1	3.3	0.8	2.0	1.4
7	59.1	0.3	10.0	2.4	6.0	4.1
11	92.7	0.4	10.0	3.1	6.0	4.6
1	8.4	0.03	3.3	0.2	2.0	1.1
386	3,254.4					

in the woods, in the successional sequence. The order in which these trees appeared in the Island's forest succession, as interpreted by us, is diagrammed in Figure 5, and discussed below.

In the older forests (Duff's Woods, Victory Woods, and Cooper's Woods), the single dominant species is *Acer saccharum.* Next in importance in these sites is *Celtis occidentalis*, whose importance value is almost equal to that of *Acer saccharum* in Cooper's Woods, but which is far less important in both Victory Woods and Duff's Woods (Table 4). Both species are also present in the younger forests, but only *Celtis* occurs in significant numbers there. This would suggest that *Celtis occidentalis* is a long-ranging successional species in the South Bass Islands woods, appearing fairly early in the successional sequence and lasting as late as the latest successional stage represented on the Island. In contrast, *Acer saccharum*, which is only of minor importance in the younger stands, but which dominates the older woods, must be a species mainly characteristic of late successional stages, and probably of full climax as well (Braun, 1950).

Species that are more common in the younger woods, in addition to *Celtis occidentalis*, are *Juniperus viriniana*, *Morus alba*, *Lonicera xylosteum*, and *Acer platinoides* in Heineman's Woods, and *Prunus serotina* in Miller's Woods. *Morus alba*, *Juniperus viginiana*, and *Prunus serotina* are only of very minor importance in the older stands, being considered early successional species, as they have been accepted by McCormick (1968).

Juniperus virginiana is present throughout the Island, in at least small numbers, wherever rock is shallow and Romeo soils occur (or on bare rock), except in the older, deeply shaded woods, although even in such places, occasional dead individuals may be encountered. It is only abundant, however, along the rocky shorelines and in Heineman's Woods. This latter abundance is best explained as a result of the intensive grazing of this area by about 12 cows between during the period between 1944 and 1946 (Louis Heineman, personal communication, 1968). At that time, most of the more palatable broad-leaved trees were apparently eliminated, permitting the cedar to increase in numbers and size in the pasture.

Lonicera xylosteum, which is also present in Heineman's Woods, is a popular horticultural honeysuckle plant, and probably represents an escape from man's plantings. This species is moderately common along the more open roadsides and at the edges of lawns in many parts of the Island, which suggests that the plant

TABLE 4

Importance values for trees, saplings, and seedlings in all five woods sampled on South Bass Island, Ohio. These values are based on 100 per cent. Woods are arranged in inferred order of successional sequence, from early (left) to late (right)

	TREES				
Species	Heineman's Woods	Miller's Woods	Cooper's Woods	Victory Woods	Duff's Woods
Community name	*Cedar*	*Young Hackberry*	*Maple-Hackberry-Basswood*	*Maple-Hackberry-Basswood*	*Maple-Oak-Hickory*
Acer saccharum	1.3	15.1	27.8	57.8	38.2
Celtis occidentalis	20.3	59.3	26.5	19.7	8.3
Prunus serotina	2.4	10.5	1.2	0.9	4.0
Tilia americana		8.1	19.8	9.6	6.4
Quercus muhlenbergii		3.2		1.2	0.9
Fraxinus quadrangulata		1.8		2.5	4.5
Carya sp.		1.0		1.1	14.1
Ulmus rubra			0.5	5.0	1.5
Ostrya virginiana			5.0	1.3	6.6
Quercus alba					9.1
Quercus rubra					4.1
Morus alba	15.2		3.4	0.9	1.6
Lonicera xylosteum	11.4		7.8		0.7
Fraxinus pennsylvanica			3.8		
Juglans nigra	2.5		2.6		
Juniperus virginiana	36.6		1.1		
Acer platinoides	10.0				
Cornus drummondi	0.3				
Vitis sp.		1.0	0.5		
Ribes sp.					

TABLE 4—(*Continued*)

	SAPLINGS				
Species	Heineman's Woods	Miller's Woods	Cooper's Woods	Victory Woods	Duff's Woods
Community name	*Cedar*	*Young Hackberry*	*Maple-Hackberry-Basswood*	*Maple-Hackberry-Basswood*	*Maple-Oak-Hickory*
Acer saccharum	5.9	50.4	41.9	61.4	58.4
Celtis occidentalis	3.3	28.2	32.4	27.3	21.4
Perunus serotina	5.9	10.8	8.3	4.2	7.8
Tilia americana		7.2	1.4	1.4	
Quercus muhlenbergii					
Fraxinus quadrangulata				4.6	7.8
Carya sp.					
Ulmus rubra					2.3
Ostrya virginiana					2.3
Quercus alba					
Quercus rubra					
Morus alba	2.2			1.1	
Lonicera xylosteum	75.5	3.4	12.7		
Fraxinus pennsylvanica			3.3		
Juglans nigra					
Juniperus virginiana					
Acer platinoides	3.6				
Cornus drummondi	1.0				
Vitis sp.					
Ribes sp.	2.6				

TABLE 4—(*Continued*)

SEEDLINGS

Species	Heineman's Woods	Miller's Woods	Cooper's Woods	Victory Woods	Duff's Woods
Community name	*Cedar*	*Young Hackberry*	*Maple-Hackberry-Basswood*	*Maple-Hackberry-Basswood*	*Maple-Oak-Hickory*
Acer saccharum	7.8	47.5	54.6	85.4	78.0
Celtis occidentalis	11.5	37.8	30.3	8.5	
Prunus serotina	5.8	14.7	8.1	2.3	8.0
Tilia americana			7.0	1.9	3.4
Quercus muhlenbergii					
Fraxinus quadrangulata					7.2
Carya sp.					
Ulmus rubra				1.9	
Ostrya virginiana					3.4
Quercus alba					
Quercus rubra					
Morus alba					
Lonicera xylosteum	69.9				
Fraxinus pennsylvanica					
Juglans nigra					
Juniperus virginiana					
Acer platinoides	5.0				
Cornus drummondi					
Vitis sp.					
Ribes sp.					

responds best to relatively open conditions, such as the conditions which must have existed in Heineman's Woods at the time when grazing was just being discontinued, when the site was probably an open cedar meadow. Earlier invasions of *Lonicera xylosteum* may have taken place, but grazing would probably have prevented this broad-leaved plant from becoming well established then. Since the time of its successful invasion, other broad-leaved trees have also come in, while both cedar and especially honeysuckle have continued to persist. At the present time, a number of the cedar trees and some of the honeysuckle plants are dead, probably because of the increased shade as the canopy became closed by the taller invading species (*Acer platinoides*, *Morus alba*, and *Celtis occidentalis*).

Acer platinoides is another species whose occurrence in Heineman's Woods is probably due to escape from plantings. A number of large trees of this species occur along the western edge of Heineman's Woods, where they were planted many years ago. These trees probably provided the seed source for the individuals encountered in the sampling, an interpretation supported by the fact that the number of these trees decreases eastward, away from the proposed source.

The principles outlined here, by which the positions of *Morus alba*, *Prunus serotina*, *Celtis occidentalis*, and *Acer saccharum* in the successional sequence were defined, were applied to all species observed, and an effort was made to relate their occurrence to the full sequence of successional stages occurring on the Island. This evaluation, though guided in large part by the data presented in Tables 2, 3, and 4 (and also in McCormick, 1968), is also based in part on informal observations and is therefore somewhat objective. Despite this, the final interpretation of the position of each species in the successional sequence, as shown in Figure 5, seems meaningful to us. It was partly on the basis of these interpretations that the order of each woods studied in the successional sequence of communities (Table 4) was inferred. And it is all these data—the inferred position of each species in the successional sequence (Figure 5), the order of each woods studied in

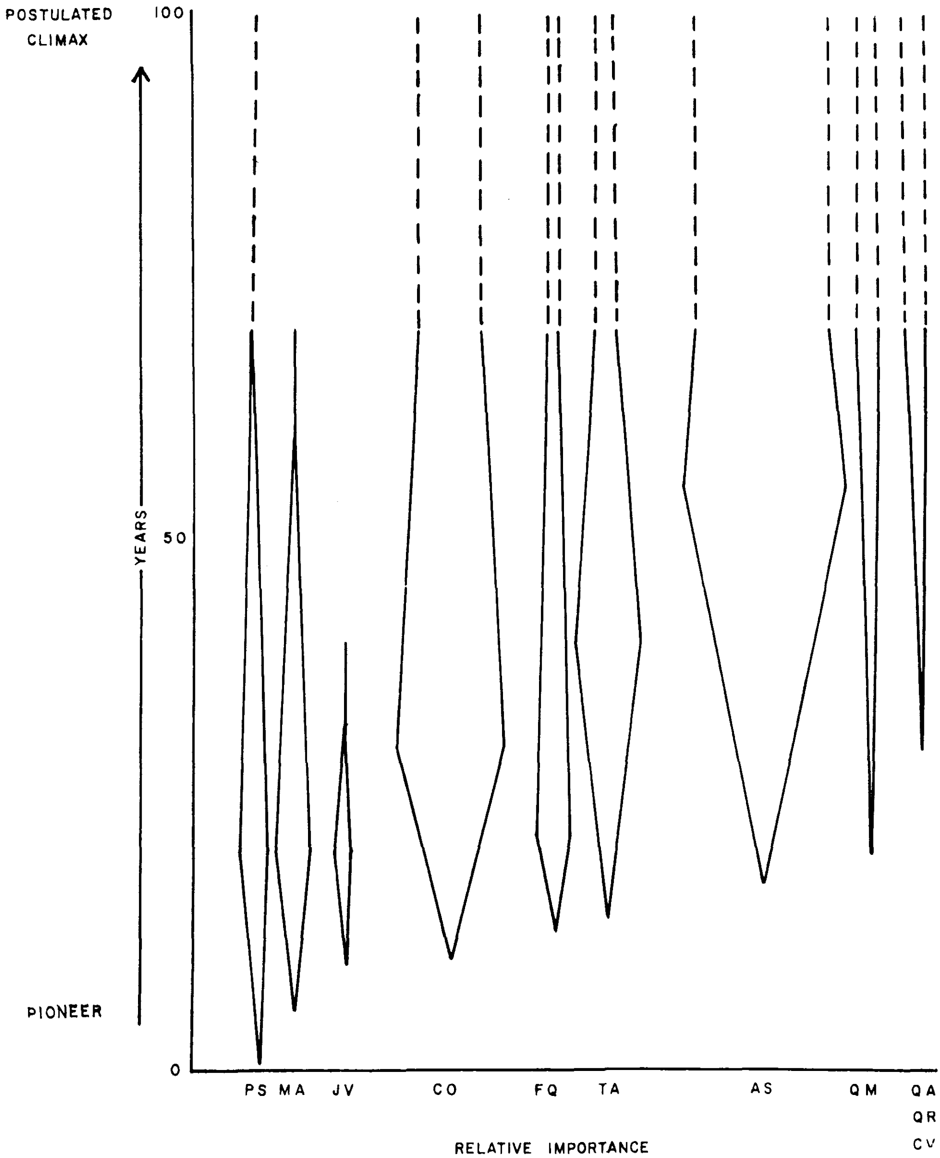

FIGURE 5. Relative importance of tree species in succession through time. The width of the individual histograms indicates the relative importance of each species in relation to each other at any given time interval in the successional sequence. The solid lines indicate the successional pattern to the present; the dashed lines represent the postulated projection of succession through future time. Species symbols are: PS = *Prunus* sp., MA = *Morus alba*, JV = *Juniperus virginiana*, CO = *Celtis occidentalis*, FQ = *Fraxinus quadrangulata*, TA = *Tilia americana*, AS = *Acer saccharum*, QM = *Quercus muhlenbergii*, QA = *Quercus alba*, QR = *Quercus rubra*, CV = *Carya* sp.

that sequence (Table 4), and the concepts employed in these determinations—that are drawn on to interpret the probable nature of the Island's forest climax, as described below.

There is only one type of woodland community on South Bass Island in which *Acer saccharum* is completely lacking. This occurs in those places where rock is quite deep and is covered by clay-rich glacial till, in which a Hoytville soil is developed. Because of the flatness of such areas and the relative impermeability of the clay-rich till, these areas are poorly drained and may have standing water present for much of the spring. Despite this poor drainage, most of the flat, rock-free sites have been used for growing grapes, though many of these vineyards have now been abandoned. In only a few of these areas have cultural practices since abandonment of the land (lack of mowing, grazing, etc.), permitted the invasion of woody plants. The biggest trees in such a site occur east of Columbus Avenue on the northeastern part of the Island (in Stand VII of McCormick, 1968), and are mainly *Acer negundo* and *Fraxinum pennsylvanica* var. *subintegerrima* (called *Fraxinum americana* in McCormick's paper, but here identified as *F. pennsylvanica* var. *subintegerrima* on the basis of careful comparison with Stone Laboratory's herbarium specimens) (shown as "Box Elder-Green Ash" in fig. 4). This ash, which is the common ash along the shorelines, exhibits relatively rapid growth and forms a fairly dense stand. Our field reconnaissance and McCormick's data (1968) indicate that *Celtis occidentalis* is invading this woodlot, and apparently is competing successfully with the box elder and green ash. However, because no other woodlots occur on this same kind of substrate on South Bass Island, it is impossible to predict either the successional sequence or the climax that would result on this kind of site.

An estimation of both the successional sequence and the inferred climax on the shallow, rocky soil (Romeo), on the other hand, is quite possible. Based on the data from all the woodland sites, and the interpretation given in Figure 5, the earliest stages of succession on South Bass Island should be characterized by *Prunus serotina*, and subsequently by *Morus alba* (an interpretation which agrees with the results of McCormick, 1968). These are followed by the appearance of *Juniperus virginiana* and *Celtis occidentalis*. This is the stage represented by Heineman's Woods, although the picture there is somewhat confused by the presence of the "escaped" species, and by the influence of the past grazing. On especially open, dry, rocky sites, however, such as on the cliffs of the northwest shore, *Juniperus virginiana* is commonly the main tree species present.

With continued increase in *Celtis occidentalis*, a stage represented by that in Miller's Woods is reached. A number of other, smaller, young woodlots west of Miller's Woods, and locally in other sites on the Island, also appear to belong to this stage (Young Hackberry) (fig. 4).

Fraxinus quadrangulata and *Tilia americana* are interpreted to appear next, before any significant numbers of *Acer saccharum* occur. This interpretation is based on informal observations of unsampled sites and especially on as-yet-unpublished data from the woods occurring just northeast of the lighthouse, along the northwest shore (the area now being studied as a master's degree project), a community called Hackberry-Blue Ash (fig. 4).

Once *Acer saccharum* appears, its importance increases fairly rapidly and then decreases as other mature-stage species (fig. 5) appear and increase in importance, as demonstrated by the values for it in Cooper's Woods (27.8), in Victory Woods (57.8), and in Duff's Woods (38.2) (Table 4). The especially high importance value for this species in Victory Woods is probably partly a result of continued moderate disturbance by man, disturbance (people and vehicles entering the woods to dump waste cans and bottles of all kinds) that apparently was especially pronounced in the later years of the Victory Hotel, which once stood just to the southwest (Frohman, 1971), but has unfortunately persisted into more recent times. This disturbance would tend to reduce the numbers of less tolerant species and encourage the omnipresent maple seedlings. With the increasing importance of *Acer saccharum*, the earliest three species (*Prunus serotina*, *Morus alba*, and *Juniperus virginiana*) are almost eliminated, and *Celtis occidentalis* begins to decline. *Quercus muehlenbergii*, *Q. alba*, *Q. rubra*, and *Carya* sp. appear late, and occur only as scattered individuals, even in the most mature forests. Their collective total importance value is 0 in Cooper's Woods, and only 3.3 in Victory Woods, but 28.2 in Duff's Woods—they are the late mature-stage species whose appearance is mainly responsible for the reduction in importance of *Acer saccharum* mentioned above. Of these species, *Quercus muehlenbergii* tends to occur especially commonly on sites where limy bedrock is very shallow (Braun, 1961), thus explaining the apparently anomalous value of 3.2 for this species in Miller's Woods, in a community found early in the successional sequence.

The forest climax suggested by the succession described above would, without question, contain *Acer saccharum* in great abundance, while *Celtis occidentalis* would be present, but with much less importance than at earlier stages. Certainly the early successional species, *Prunus serotina*, *Morus alba*, and *Juniperus virginiana*, would have mostly disappeared. A few individuals of *Fraxinus quadrangulata* would probably still be present, in large part because of the lime-rich substrates (Braun, 1961), though this tree would be decreasing in numbers. *Tilia americana* would probably occur in somewhat greater numbers than the ash, also partly in response to the limy substrates (Scholz, 1958), but, based on the reproductive data (Tables 2 and 4), any significant abundance is unlikely. There seems to be no way for oaks or hickories to increase greatly beyond their present maximum, so their importance values would probably remain low. That they were truly a part of the early Island forests is supported by the large size of the few oaks and hickories still present, especially in Duff's Woods; indeed, two large individuals of *Quercus alba* (28 and 34 inches DBH) occur in Duff's Woods north of the area sampled. The lack of beech is not surprising; beech trees normally occur in areas of somewhat more moisture (Fritts and Holowaychuk, 1959) and lower pH (Lamotte Company, No date).

All of these observations and data suggest a climax dominated by *Acer saccharum*, with a moderate amount of *Celtis occidentalis*, decreasing numbers of *Fraxinus quadrangulata*, and small, possibly slightly increasing numbers of *Tilia americana*, *Quercus* (all species), and *Carya* sp. This is hardly "maple-basswood" (Braun, 1950), "oak-sugar maple" (Gordon, 1966), or "oak-maple-basswood" (Gordon, 1969; Hudgins, 1943; Core, 1948; Langlois and Langlois, 1948). The amounts of basswood and oak are simply not enough for these terms to represent adequately the unique vegetation of the Island. The importance of *Celtis occidentalis* is certainly greater than that of either oak or basswood, but no mention is made of it. The association names given in Figure 4 may also be inadequate, but together they represent an effort to identify in a meaningful way the significant variations in the arboreal vegetation observed on South Bass Island.

In the climax vegetation described above, if the amounts of oak and hickory were increased, and the amount of basswood and perhaps sugar maple were decreased, the vegetation would indeed approximate the "oak-sugar maple" association of northern Ohio (Gordon, 1966). The presence of basswood is explained as a projection eastward from the extensitve maple-basswood area of Wisconsin and Minnesota (Braun, 1950; Sears, 1941). It is less easy to explain why there are so few oaks and hickories.

The small numbers of oaks and hickories have been interpreted to be a result of selective cutting in the past. Unfortunately there is no evidence for this, either in the form of stumps or in the literature. Indeed, some early literature claims that most of the island vegetation was cedar, probably because of the abundance of this species along the rocky shores of the island (Core, 1948).

It is also possible that neither oaks nor hickories belong in the natural vegetation of the Island. Certainly some oaks and hickories have been planted locally, as shown by early photographs of the town of Put-in-Bay and some of the adjacent parks, as demonstrated by the linear arrangements of some trees, and as reported by some older island resident (Paul Webster, personal communication, 1969). It is unlikely, however, that such planting went on in an apparently mature forest such as Duff's Woods.

Differences in seed dispersal may be important. Certainly wind-transported seeds of *Acer saccharum* should be well distributed here on the Island. Seeds of *Celtis occidentalis*, which is second to maple in importance, are effectively distributed by birds, whereas the dominant method of distribution of acorns and hickory nuts is by animals, mainly squirrels. Squirrels occur in abundance on Island, so this seems to provide no explanation for the far smaller numbers of oaks and hickories, unless the shallow rock prevents adequate burial of these propagules by squirrels, which would make them more readily available as food for the mice that are present (Fall, *et al.*, 1968; Enders, 1972), a combination of possibilities that seems reasonable, but does not appear adequate to explain entirely the restricted numbers of these species of trees.

Initially it was hoped that differences in substrate might reveal patterns which would explain the presence of the oaks and hickories in only a few areas. Unfortunately no such relationship was found; forests of hackberry and sugar maple occur on the same substrates (Romeo soils with local rock outcrops) as do the forests containing the oaks and hickories.

The best explanation for the extremely limited numbers of oaks and hickories and the great importance of sugar maple appears to be that the organic-rich, moisture-retaining (Lutz and Chandler, 1946) Romeo soils are especially favorable for sugar maple (similar limestone substrates on the Upper Peninsula of Michigan were observed by the junior author in September, 1971, to support similar stands of almost pure sugar maple). "Yield and quality of sugar maple stands increase as soil fertility and moisture conditions improve. The species thrives only on fertile, moist, and well-drained soils" (Godman, 1957). The organic-rich Romeo soils are indeed fertile and provide, at the same time, a moist and well-drained substrate, conditions which, according to Godman (1957), yield the highest concentrations of sugar maple. Such concentrations are additionally increased where moderate disturbance, such as characterizes most of the woodlots of the Island, has encouraged the contribution of maple saplings to the canopy. Oaks, on the contrary, are very slow growers (Racine, 1971), a factor which would tend to reduce their ability to compete with the sugar maple.

According to our interpretation, then, the sites are so favorable for sugar maple that seedlings and saplings are especially abundant (which is true—Tables 3 and 4, especially in Victory Woods), so that any opening in the canopy is quickly filled by the young maple plants, preventing the somewhat slower growing (Racine, 1971) oak and hickory seedlings from taking advantage of the canopy break. It is also possible that any difficulty encountered by squirrels in burying acorns and hickory nuts in this rocky substrate, and the availability of such inadequately buried nuts as food for mice (Fall, *et al.*, 1968; Enders, 1972), may help to restrict the development of these species. Throughout a very long period of undisturbed forest growth, the chances are that a very few oak and hickory seedlings may have the opportunity to grow into full-sized trees, increasing *very* slowly the importance of these species in the Island's most mature, least disturbed woodlots. The slow modification theorized here would eventually allow the numbers of oaks and hickories to approach but not to equal their number in the equivalent mainland community, though the time required would be far longer than the short interval since the cutting of most of the Island's timber. Even if such a long period of undistrubed growth were possible, the favorable nature of the substrate for *Acer*

TABLE 5

Occurrence of tree species on the other Erie Islands

Key to abundance numbers:
1—rare, scattered individuals
2—occasional, few individuals
3—common only in a few local sites
4—generally common
5—abundant
6—abundant and dominant
X—no abundance data available

	Plant Species	South Bass[1]	Middle Bass[1]	North Bass[1]	Sugar	Ballast	Lost Ballast[2]
1.	*Acer saccharum*	6	5	6	6	5	—
2.	*Celtis occidentalis*	6	6	6	6	6	5
3.	*Tilia americana*	4	4	2	2	—	—
4.	*Fraxinus guadrangulata*	3	2	2	—	3	—
5.	*Fraxinus pennsylvanica* var. *subintegerrima*[6]	3	3	3	3	—	—
6.	*Fraxinus pennsylvanica* var. *pennsylvanica*[6]	2	2	2	3	—	—
7.	*Fraxinus americana*	1(?)	—	—	—	—	X
8.	*Acer saccharinum*	2	3[6]	—	1	2	X
9.	*Juniperus virginiana*[7]	3	3	1	1	2	—
10.	*Ulmus* sp.	2	2	1	1	—	X
11.	*Ostrya virginiana*	2	2	1	2	—	—
12.	*Morus* sp. (mostly *M. alba*)	2	2	2	2	2	X
13.	*Prunus* sp.[8]	3	3	2	2	—	X
14.	*Acer negundo*[9]	3	2	3	—	—	—
15.	*Quercus muehlenbergii*[10]	2	2	—	2	—	—
16.	*Quercus alba*	2	—	1	—	—	—
17.	*Quercus rubra*	2	1	1	2	—	—
18.	*Quercus macrocarpa*	—	1	—	—	—	—
19.	*Carya* sp. (mostly *C. ovata*)	2	2	2	2[11]	—	—
20.	*Populus deltoides*[12]	3	2	3	2	—	6
21.	*Salix* sp.	3	3	3	2	1	3
22.	*Juglans nigra*	3	—	—	—	—	—
23.	*Platanus occidentalis*	—(?)	—	—	1	—	—
24.	*Robinia pseudo-acacia*	—	3	3	—	—	—
25.	*Gleditsia triacanthos*	—	—	—	1	—	—
26.	*Gymnocladus dioica*	—	1	—	—	—	—

[1]Based in part on systematic vegetational sampling of small selected sites.
[2]Data all or in part drawn from Duncan and Stuckey 1970.
[3]Date provided by Mr. Marvin Roberts and Mr. Thomas Duncan in 1970.
[4]Data in part through the courtesy of Dr. Mildred Miskimmen.
[5]Data all or in part provided through the courtesy of Mr. Thomas Duncan and Dr. Ronald L. Stuckey.
[6]Mostly restricted to sites along lake shore, with exception of green ash on Sugar and on Kelley's Islands. (Restriction of red and green ash to wet shoreline sites first reported to us by Dr. Ronald L. Stuckey, 1967.)
[7]Common in oldfields and old vineyards where bedrock is very shallow, or on dolomite cliffs along shore; maintained by past pasturing on South Bass, Middle Bass, and Kelley's Islands and perhaps on other islands also. Rare on islands lacking or mostly lacking shallow or exposed bedrock.

saccharum would probably prevent the number of oaks and hickories on the Island from truly approaching the number of their mainland counterparts.

ARBOREAL VEGETATION OF OTHER ERIE ISLANDS

The occurrence and abundance of the species of trees mapped on South Bass Island were observed on other islands in the Erie Archipelago in order to compare them with the South Bass Island data. Of these areas, systematic sampling was

TABLE 5—(*Continued*)

Green[1, 2]	Starve[1, 2]	Mouse[3]	West Sister	Middle Sister[2]	East Sister	Hen[2, 4]	Kelley's	Middle	Pelee[5]
6	—	4	—	X	5	5	5	3	X
5	6	6	6	6	6	6	6	6	X
2	—	2	1	—	2	—	2	1	X
3	—	1	1	—	—	X	3	1	X
3	1	X	—	—	4	X	4	4	X
X	1	—	—	—	2	—	3	3	X
X	—	X	—	—	—	—	1	—	X
X	X	—	—	—	2[6]	—	2	1[6]	—
3	—	2	—	—	—	X	5	2	X
2	2	2	—	X	1	X	2	1	X
1	—	—	—	—	—	—	2	—	X
2	1	2	—	—	—	—	2	2	X
3	—	5	—	X	—	X	3	2	X
—	—	—	—	—	—	—	3	1	X
2	—	—	—	—	2	—	2	5	X
—	—	—	—	—	—	—	—	—	X
—	—	—	—	—	—	—	—	—	X
—	—	2	—	—	—	—	—	1	X
—	—	—	—	—	2	—	—	—	X
2	2	X	—	X	4	—	3	2	X
2	3	—	—	X	3	—	2	2	X
—	—	—	—	—	—	—	1	1	X
—	—	—	—	—	—	—	—	1	X
—	—	—	—	—	2	1	—	1	—
—	—	1	—	—	—	—	—	1	—
X	—	4	—	X	—	X	—	2	X

[8]Commonly in initial arboreal succession in old vineyards, locally persisting for some time.

[9]Found in flat areas of till substrate where bedrock is at least six feet deep, or along shorelines. The only tree observed on Big Chicken Island in 1966 was a box-elder, though this tree had disappeared by 1969 according to Mr. Thomas Duncan (see also Duncan and Stuckey, 1970).

[10]Occurs mainly where limestone or dolomite bedrock is especially shallow.

[11]In addition, one specimen of *Carya cordiformis* was found on Sugar Island.

[12]In local sites along shores and in some low swampy inland sites; also locally present in dry abandoned quarries on Kelley's Island.

done only in local sites on Middle Bass, North Bass, and Green Islands, all the other data being obtained from casual observations of the tree species. Information was also obtained from the 1970 publication of Duncan and Stuckey, and from unpublished data supplied by Dr. Ronald L. Stuckey, Mr. Thomas Duncan, Mr. Marvin Roberts, and Dr. Mildred Miskimmen. All these data are presented in Table 5.

A comparison of the data in this table (Table 5) with the vegetation data given earlier for South Bass Island reveals great similarities. The forests on all these islands, with the exception of those on West Sister and on the very tiny islands that are mostly shoreline, are dominated by either *Acer saccharum* or *Celtis occidentalis*, depending basically on the depth of the soil, which is directly related to the recency of tree cutting and other human disturbance. Where forests with tall trees and closed canopies are present, associated with fairly deep organic-rich soils, *Acer saccharum* dominates, but *Celtis occidentalis* is fairly abundant. Where the soil is more shallow and/or disturbance appears to have been relatively recent, *Celtis occidentalis* dominates and *Acer saccharum* is a close second. As is true on South Bass Island, these species are most common in areas where bedrock (domomite on most islands; limestone on Kelley's, Middle, and Pelee Isalnds) is shallow. In local areas of deeper rock (commonly associated with swamps) on the three larger islands (North Bass, Middle Bass, and Kelley's Islands), species of *Populus*, *Salix*, and *Ulmus* are common in the wetter areas, and *Fraxinus pennsylvanica* var. *subintegerrima* and *Acer negundo* are present in the somewhat dryer sites. These trees are also present in places along the islands' shores, together with *Franxinus pennsylvanica* var. *pennsylvanica* (red ash) and, locally, *Acer saccharinum.*

On all islands large enough to have had vineyards that are now abandoned, oldfield trees present are *Prunus* sp. and *Morus alba.* In addition, *Acer negundo* occurs where bedrock is deeper, and *Juniperus virginiana* is present in abundance wherever the bedrock is shallow and there has been intensive grazing or other disturbance.

Oaks and hickories, whose presence on South Bass Island represented a problem, do not occur on the smaller islands. In general they are present only on the larger islands and only in fairly mature woods, such as those on Sugar, Pelee, and locally North Bass Islands, or as scattered individuals in generally open areas, such as on Middle Bass Island. *Quercus muehlenbergii* is present on more islands than are the other oaks and hickories, apparently because of its favorable response to areas of shallow limestone (Braun, 1961).

The tree composition of West Sister Island is especially interesting, for a limited survey revealed no *Acer saccharum* at all. Despite the presence of forests characterized by large, tall trees and closed canopies, all the trees on the island, with only a very few exceptions, are *Celtis occidentalis.* The exceptions are two individuals of *Tilia americana* and one of *Fraxinus quadrangulata* that were found on the northwest shore of the island. The absence of sugar maple on this island may be due to its isolation. West Sister is 15 miles from the nearest land. It lies upwind from the maples on South Bass Island (relative to the prevailing westerlies) and also upcurrent, in terms of the lake currents. The nearest mainland vegetation is swamp forest, which lacks *Acer saccharum,* so that the distance to the nearest stands of this species, other than those on the Erie Islands, is at least 35 miles (representing 20 miles of water and 15 miles of city, cultivated fields, and swamp forest). It would be difficult for maple seeds to be blown that far. Seeds of *Celtis occidentalis,* on the other hand, are drupes that are most palatable to birds, and so could well have been "planted" in this manner to form this West Sistern Island woodland.

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LITERATURE CITED

Braun, E. L. 1950. Deciduous forests of eastern North America. The Blakiston Co., Philadelphia. 596 p.

——— 1961. The woody plants of Ohio. Ohio State Univ. Press, Columbus. 362 p.

Buell, M. F., A. N. Langford, D. W. Davidson, and **L. F. Ohmann.** 1966. The upland forest continuum in northern New Jersey. Ecology 47(3): 416–432.

Carman, J. A. 1927. The Monroe division of rocks in Ohio. J. Geol. 35(6): 481–506.

——— 1946. The geologic interpretation of scenic features in Ohio. Ohio J. Sci. 46(5): 241–283. Also Ohio Div. of Geol. Survey Reprint Series No. 3.

Core, Earl L. 1948. The flora of the Erie Islands, an annotated list of vascular plants. Ohio State Univ., Franz Theodore Stone Lab. Contr. 9. 106 p.

——— 1971. Silvical characteristics of the five upland oaks. p. 19–22 *in* White, D. E., and B. A. Roach. Oak Symposium Proceedings. Northeast Forest Exp. Sta., U. S. Forest Service, Upper Darby, Pa. 161 p.

Curtis, J. T., and **R. P. McIntosh.** 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. Ecology 32: 476–496.

Duncan, Thomas, and **Ronald L. Stuckey.** 1970. Changes in the vascular flora of seven small islands in western Lake Erie. The Mich. Bot. 9: 175–200.

Enders, John. 1972. Small mammals in the Lake Erie region of Ohio. Abstracts of The Ohio Acad. Sci. 81st Ann. Mtg., Marietta, Ohio.

Fall, Michael W., William B. Jackson, and **Michael L. Carpenter.** 1968. The occurrence and origin of small mammals on the islands and peninsulas of western Lake Erie. Ohio J. Sci. 68(2): 109–116.

Forsyth, Jane L. 1971. Geology of the Lake Erie Islands and adjacent shores. p. 1–18 *in* Forsyth, Jane L., Compil., Geology of the Lake Erie Islands and adjacent shores. Mich. Basin Geol. Soc. Ann. Field Excursion guidebook. 63 p.

——— In Prep. Geology, Soils, and Geologic History. *In* Stuckey, Ronald L., and Thomas Duncan. Flora of the Erie Islands, its origin, history, and change. Ohio Biol. Survey. In Prep.

Fritts, Harold C., and **Nicholas Holowaychuk.** 1959. Some soil factors affecting the distribution of beech in a central Ohio forest. Ohio J. Sci. 59(3): 167–186.

Frohman, Charles E. 1971. Put-in-Bay . . . Its History. The Ohio Hist. Soc., Columbus. 156 p.

Gordon, R. B. 1966. Natural vegetation of Ohio at the time of the earliest surveys. Ohio Biol. Surv. (map).

——— 1969. The natural vegetation of Ohio in pioneer days. Ohio Biol. Survey, n.s., 3(2). 109 p.

Hudgins, B. 1943. The South Bass Island community (Put-in-Bay). Econ. Geog. 19: 16–36.

LaMotte Company. No date. LaMotte Soil Handbook. LaMotte Chemical Products Co., Chestertown, Maryland. 59 p.

Lutz, Harold J., and **Robert F. Chandler, Jr.** 1946. Forest soils. John Wiley and Sons, New York. 514 p.

McCormick, Jack. 1968. Vegetation in fallow vineyards, South Bass Island, Ohio. Ohio J. Sci. 68(1): 1–11.

Mohr, E. B. 1931. The geology of the Bass Islands. Unpub. M.Sc. thesis, The Ohio State Univ., Columbus. 62 p.

Paschall, A. H., J. G. Steele, G. W. Conrey, and **S. W. Phillips.** 1938. Soil survey of Ottawa County, Ohio. U. S. Dept. Agri., Washington, D.C. 38 p.

Racine, Charles H. 1971. Reproduction of three species of oak in relation to vegetational and environmental gradients in the southern Blue Ridge. Bull. Torrey Bot. Club 98(6): 297–310.

Scholz, H. F. 1958. Silvical characteristics of American basswood. Lake States Forest Exp. Sta., Sta. Paper 62. 17 p.

Sears, P. B. 1941. Postglacial vegetation in the Erie-Ohio area. Ohio J. Sci. 41: 225–234.

Sparling, Dale R. 1965. Geology of Ottawa County, Ohio. Unpub. Ph.D. dissert., The Ohio State Univ., Columbus. 265 p.

——— 1970. The Bass Islands Formation in its type region. Ohio J. Sci. 70(1): 1–33.

——— 1971. Bedrock geology of Ottawa County, Ohio. p. 19–29 *in* Forsyth, Jane L., compil. Geology of the Lake Erie Islands and adjacent shores. Mich. Basin Geol. Soc. Ann. Field Excursion guidebook. 63 p.

Verber, J. L. 1955. The climates of South Bass Island, western Lake Erie. Ecology 36: 388–400.

Verber, J. L., and **D. H. Stansbery.** 1953. Caves in the Lake Erie Islands. Ohio J. Sci. 53: 358–362.